Understanding far-field and near-field effects of injection activities on induced seismicity in Oklahoma

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Many previous studies demonstrate that the sharply increased seismicity rate in Oklahoma is mainly due to wastewater disposal. While this is clear at regional scales, it is unclear how far-field and near-field injection affects seismicity evolution in space and time. It is also unclear what is the role of hydraulic fracturing activities in the evolution of individual earthquake sequences in areas with wastewater disposal. In this study, we combine multiscale seismicity analysis and pore pressure modeling to understand the influence of far-field and near-field effects. We start with large-scale analysis to understand temporal relationship and spatial migration of earthquakes at several regions associated with areas with high-rate injection wells. Then, we analyze spatiotemporal migration within individual clusters. Finally, we performed detailed analysis for two induced sequences in central Oklahoma (Guthrie and Cushing sequences), combining seismological analysis and pore pressure modeling to understand the effect of far-field and near-field wastewater injection and hydraulic fracturing activities on the temporal evolutions of the two earthquake sequences.

The multiscale spatiotemporal analysis suggests that at large scale, several regions with concentrated high-rate injection well clusters exhibit statistically significant far-field migration pattern. Based on these migration patterns, we determine hydraulic diffusivities between 0.75m^2/s and 2 m^2/s, which is approximately consistent with the expected ranges for the Arbuckle Group measured in lab and in the field. At small scales, the percentage of diffusive migration clusters and ranges of diffusivities are similar to other tectonic regions for crustal clusters (i.e., Southern California). With detailed analyses of two induced sequences, we find that local near-field injection activities are more closely related with temporal evolution of the sequences, while far-field injection may contribute to the initial rupture within the fault zone.

Keywords: induced seismicity, spatial migration, wastewater disposal

